(12) UK Patent Application (19) GB (11) 2 293 523 (13) A

(43) Date of A Publication 27.03.1996

(21) Application No 9418960.2

(22) Date of Filing 21.09.1994

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(51) INT CL[6]
H04K 3/00, H04Q 7/28

(52) UK CL (Edition O)
H4L LBSF
U1S S2204 S2213

(56) Documents Cited
US 5235598 A

(58) Field of Search
UK CL (Edition N) H4L
INT CL[6] H04K, H04Q

(54) **Radio base station equipment with non-constant offset duplex trunking**

(57) A trunking radio system having a base station (13 - 20) and at least one remote unit (21, 22). Commands are transmitted on an outbound control channel frequency (RXCC) and on an inbound control channel frequency (TXCC) separated from the outbound control channel frequency by a given duplex separation. As a protection against jamming, commands are transmitted from time to time from the base station to the at leat one remote unit to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency such that the duplex separation between the inbound control channel frequency and the outbound control channel frequency is varied.

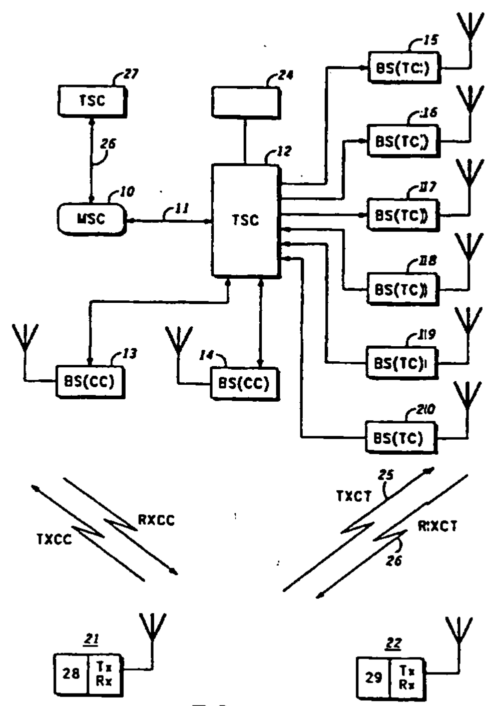

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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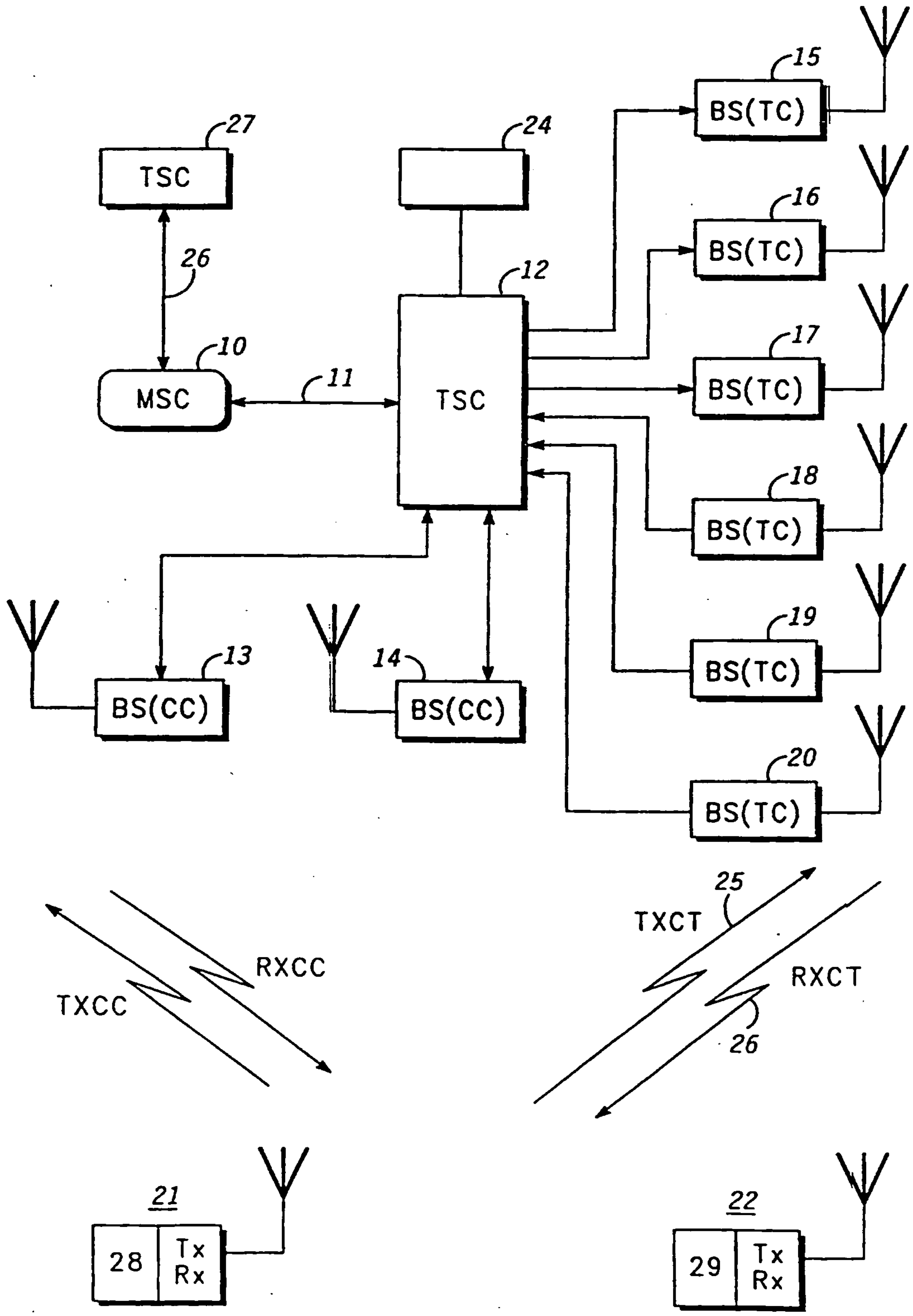

27
TSC
26
10
MSC
11
24
12
TSC
15
BS(TC)
16
BS(TC)
17
BS(TC)
18
BS(TC)
19
BS(TC)
20
BS(TC)
13
BS(CC)
14
BS(CC)
RXCC
TXCC
TXCT
25
RXCT
26
21
28
Tx
Rx
22
29
Tx
Rx

FIG. 1

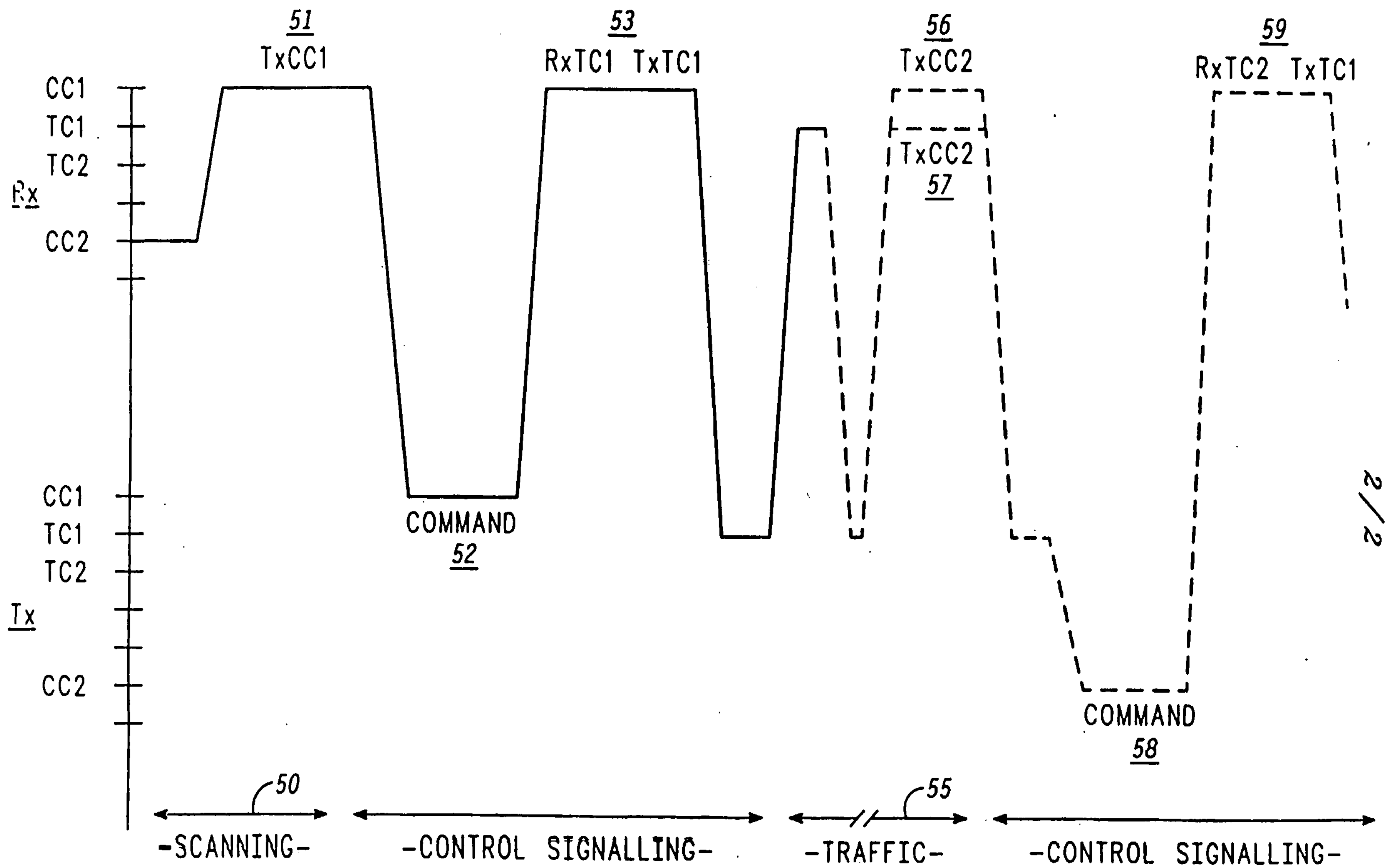
51
TxCC1
53
RxTC1 TxTC1
56
TxCC2
TxCC2
57
59
RxTC2 TxTC1
CC1
TC1
TC2
Rx
CC2
CC1
TC1
TC2
Tx
CC2
COMMAND
52
COMMAND
58
50
55
-SCANNING-
-CONTROL SIGNALLING-
-TRAFFIC-
-CONTROL SIGNALLING-

FIG. 2

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Radio Base Station Equipment with Non-Constant Offset Duplex Trunking

Field of the Invention

This invention relates to trunking radio equipment, and particularly to trunking radio base station equipment and it relates to a method of operation of a trunking radio system. The invention particularly relates to trunking radio systems with frequency division multiple access (FDMA) and it relates to time division - frequency division multiple access (TD-FDMA) systems.

Background to the Invention

In nearly all trunking systems in global use today, the spacing between base station transmit and receive frequencies (the duplex spacing) is constant within a system or within a frequency allocation. Where it is not constant, the frequency pairs are usually known, and programmed into base station and often mobile equipment.

This consistency makes such a system easy for jamming by interfering radio frequencies. As a first example,the transmit frequency of a base station is discovered, e.g. by the would-be jammer monitoring on a suitable receiver, and the duplex spacing is known; the base station receive frequency can be found by a simple addition or subtraction. The jammer may then employ a transmitter on this frequency to interfere with wanted transmissions. As a second example a simpler device would employ an oscillator of frequency equal to the duplex spacing and a mixer. Received transmissions from the base station are mixed in the mixer with the output of the oscillator. Amongst the frequencies produced by such a mixer would be the base station receive frequency. This would cause interference to wanted transmissions on that frequency. This method could have devastating results; as one device could be used to jam all base stations on a radio site where a constant duplex spacing is used.

On most trunked radio systems, mobile radios are directed to traffic (or voice) channels by means of signalling on the control channel to take part in calls. This is achieved by signalling a channel number to the mobile at the start of the call. The mobile uses the channel number signalled to calculate transmit and receive frequencies. Usually one

channel number is signalled for calculation of both mobile transmit (corresponding to base station receive) and mobile receive (corresponding to base station transmit) frequencies. This is achieved because all frequencies in the system have a constant duplex (or transmit to receive) frequency spacing.

To allow for systems where individual channels have different duplex spacings, the "Smartnet" trunked radio system permits different assignment of traffic (or voice) channel transmit and receive frequencies. The control channel signalling scheme permits mobile radios used on the system to be directed to a transmit channel number different to the receive channel number. The transmit and receive frequencies of each duplex pair are predetermined and stored in a system database. The mobile radio stores both transmit and receive frequencies for all possible control channel frequency pairs to permit signalling to take place.

European patent Application No.. EP-A-0321672 of Motorola, Inc. describes a trunked radio system which independently assigns inbound and outbound information frequencies only as required for back-and-forth communication. The channels assigned are traffic channels and the system is still potentially susceptible to jamming by jamming of the control channel, which is the principle means for allocating assignment of the inbound and outbound information frequencies.

There is a need for a trunked radio system which is more robust to jamming.

Summary of the Invention

A method of operation of a trunking radio system is provided having a base station and at least one remote unit. Commands are transmitted on an outbound control channel frequency and received commands on an inbound control channel frequency separated from the outbound control channel frequency by a given duplex separation. From time to time commands are transmitted to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency such that the duplex separation between the inbound control channel frequency and the outbound control channel frequency is varied.

In this manner, jamming of the control channel is made much more difficult, as the frequency of the inbound channel is not in a fixed relationship to the frequency of the outbound channel.

The invention applies equally to a time and frequency division multiplexed system as it applies to a pure frequency division multiplexed system.

A command may be transmitted to allocate a pair of an outbound traffic channel frequency and an inbound traffic channel frequency, where the duplex separation between the outbound traffic channel frequency and the inbound traffic channel frequency is not equal to the given duplex separation.

Commands may be transmitted to allocate pairs of outbound and inbound traffic channel frequencies, where the duplex separation between said successive pairs is varied between commands.

The various commands can be transmitted together with traffic on a traffic channel frequency. This means that a mobile which is tuned to a traffic channel will receive the commands and keep up-to-date as to the new control channel frequency. This may be achieved by embedded signalling on the traffic channel, which in a largely analog system may be sub audible signalling; or on a digital trunked system such as TETRA by means of the Stealing Channel or similar means.

The various commands can be transmitted substantially simultaneously on a control channel frequency as well as on a traffic channel frequency.

From time to time commands may be transmitted to allocate at least one of a new outbound traffic channel frequency and a new inbound traffic channel frequency such that the duplex separation between the inbound traffic channel frequency and the outbound traffic channel frequency is varied. This provided for additional protection against jamming.

In another aspect of the invention, trunking radio base station equipment is provided comprising: a transmitter for transmitting commands on an outbound control channel frequency; a receiver for receiving commands on an inbound control channel frequency separated from the outbound control channel frequency by a given duplex separation; and a controller having a channel allocation look-up table. The controller is coupled to the transmitter for controlling the transmitter to transmit commands from time to time to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency selected from the channel allocation look-up table such that the duplex separation between the selected inbound control channel frequency and the selected outbound control channel frequency is varied.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings.

Brief Description of the Drawings

FIG.1 shows an example of a trunked radio system employing the invention and

FIG.2 shows a time and frequency diagram for the operation of a mobile unit of FIG.1 in accordance with a preferred embodiment of the invention

Detailed Description of the Preferred Embodiment

Referring to FIG.1 a trunked radio system (for example operating in accordance with the MPT1327 protocol) is formed by a main switch controller (MSC) 10 connected to a number of peripheral stations formed by trunked system controllers (TSC's) 12 and 27. Each TSC is connected to the MSC 10 by a wireline connection, 11 and 26 respectively. The TSCs 12 and 27 have substantially similar resources coupled to them but for clarity only those pertaining to the TSC 12 are described here.

The TSC 12 is coupled to a number of base stations 13 and 14, typically conventional transceivers. In this manner the TSC 12 has means for transmission and reception of control messages on a number of control channels.

The TSC 12 is also coupled to a number of traffic transmission and reception frequency resources 15 to 20, typically conventional transmitters and receivers. In this manner the TSC 12 has access to a number of frequencies which are arrangable as channels which can be dynamically allocated as is described below.

Each of a number of subscriber units (mobiles) 21 and 22 has a memory resource 28 and 29 respectively, and each has a transmitter and a receiver capable of variable frequency selection matching the frequencies of the resources 13 to 20, such that they can transmit and receive control messages on one of the control channels created by the base stations 13 and 14, and can transmit and receive traffic messages to and from the TSC 12 via any one of the traffic channels created by the resources 15 to 20.

The assignment of channels is controlled by the TSC 12 which communicates with the mobiles 21 and 22 by sending control messages on

the control channel, indicating to them the traffic and control channels to which they must tune.

For explanation of the operation of the system of FIG 1, the following abbreviations will be used:

RXCC1, RXCC2 etc.- the outbound frequency of control channel 1 and control channel 2 etc. (i.e. the mobile receive frequency of control channel 1) and control channel 2)

RXTC1, RXTC2 etc. - the outbound frequencies of traffic channel 1, traffic channel 2 etc.

TXCC1 TXCC2 - the frequency of inbound control channel 1 and inbound control channel 2 etc.

TXTC1, TXTC2 etc. - the frequencies of inbound traffic channels 1, 2 etc.

At a given time TSC 12 controls base station 13 to transmit on RXCC1 and receive on TXCC1. After a period of time, for example 2 to 30 seconds, the TSC 12 performs a look-up operation in memory 24 and selects a new control channel (e.g. TXCC2 on which it wishes to receive control commands. This channel is selected either by rotation through the available receive control channel frequencies allocated in table 24, or by random selection from these frequencies. TSC 12 generates and issues a command to base station 13 for transmission on control channel RXCC1 indicating that there is to be a change in inbound control channel frequency to TXCC2. Base station 13 transmits this command on the existing channel RXCC1. Simultaneously, TSC12 issues the same command to traffic channel transmitters 15 to 17, in the form of embedded sub audible signalling on traffic to be transmitted on these channels RXTC1, RXTC2 etc.

If mobile 21 is tuned to the control channel (RXCC1) it will receive the command on the control channel and thereafter will select the new control channel (TXCC2) for later requests such as channel grant requests. If mobile 21 is tuned to a traffic channel, it receives the embedded signalling and in the same manner updates its memory 28 with the new value TXCC2.

In this manner, a change of the inbound control channel frequency is achieved while maintaining the same outbound control channel frequency. Thus the duplex spacing of the control channel is varied. This makes it more difficult to jam the control channel, because a jamming transmitter cannot simply be tuned at a fixed offset from the base station control channel frequency.

The duplex spacing of the control channel is dynamically changed by dynamically allocating transmit frequencies from a fixed pool available on a site in memory 24. In the same manner the duplex spacing can be dynamically changed by dynamically allocating transmit frequencies from a fixed pool available across a site, but not necessarily permanently allocated to that site.

The command issued through base station 13 may be encrypted (either in conjunction with or independently from any other encryption process used in the radio system) to provide further resilience against jamming.

Signalling the current control channel mobile transmit frequency through base stations 15 to 17 by suitable means such as sub audible signalling or embedded signalling permits fast re-accessing of the system by mobiles.

In a similar manner, the current control channel mobile receive frequency can be changed. Sub-audible signalling can be transmitted on the traffic channels through transmitters 15 to 17 (or other embedded signalling). This permits fast re-access of the system by mobiles, particularly where the control channel is changed dynamically at frequent intervals.

If the current control channel mobile receive frequency and the current control channel mobile transmit frequency are simultaneously changed, it is preferred that their duplex separation is not held constant.

The signalling transmitted on the traffic channels can be encrypted either in conjunction with or independently from any other encryption process used on the radio system.

To increase protection to jamming for mobiles already engaged in a call, either the traffic channel receive frequency RXCT (26) or transmit frequency TXCT (25) may be changed during the call. This is signalled to mobiles on the channel by embedded signalling, thus allowing an instant channel change with no loss of communication. If the system permits mobiles to join in a call already in progress, the change of RXCT or TXCT or both may also be signalled on the control channel RXCC.

A typical operation of a trunked radio system in accordance with the invention is illustrated in FIG 2. This is as follows.

Mobile 21 maintains in memory 28 a table of valid control channel mobile receive frequencies (i.e. base station transmit frequencies). The ordinate of FIG 2 shows, at the upper half, the mobile receive control channel and traffic channel frequencies and, in the lower half, its

transmit control channel and traffic channel frequencies. The abscissa of FIG 2 shows the progress of operation of the mobile 21 in time.

On switch-on or entering system coverage, or by some other appropriate means, the mobile 21 scans its list for a suitable control channel. This operation is represented by period 50. Once the control channel is found that matches the parameters of the mobiles search, it ceases scanning and pauses on the control channel.

The TSC 12 periodically transmits on the current control channel an identification of its currently used mobile transmit channel (TXCC1, TXCC2 etc.) In FIG 2, the example is given where the command 51 is transmitted which includes the identification TXCC1 identifying that TXCC1 is to be the current mobile transmit control channel. The mobile 21 switches to this channel and transmits command 52 requesting grant of a traffic channel. It then switches back to RXCC1 and receives command 53, which includes an indication of a receive traffic channel and a transmit traffic channel. In this example these are RXTC1 and TXTC1. It is not essential that both a receive and transmit traffic channel indication are transmitted. Indeed a channel pair with fixed duplex separation could be transmitted, but the example is given here where the receive traffic channel and the transmit traffic channel frequencies can independently be indicated by the TSC 12 transmitting on the control channel.

On receipt of command 53, the mobile 21 can commence traffic as indicated by period 55, in which it alternately switches between TXTC1 and RXTC1. At some later point in time, for example after 5 to 30 seconds, the TSC 12 generates a new "change control channel frequency" command, selecting a new inbound control channel frequency from table 24. In the example the new inbound control channel frequency is TXCC2 and this is transmitted simultaneously on control channel frequency RXCC1 as command 56 and traffic channel RXTC1 as embedded signalling command 57. In the example shown, mobile 21 will receive this command on frequency RXTC1. If mobile 22 is not currently communicating traffic, it will receive command 56 on frequency RXCC1.

Mobile 21 will update its memory 28 as to the new control channel frequency and, if it wishes to signal again to the base station TSC 12 (via base station transceiver 13 or 14) it will do so through command 58 transmitted on frequency TXCC2. In this example, the outbound control channel frequency has not been changed and any response to command 58 will be received as command 59 on RXCC1. The example is shown where command 58 is a request for a channel grant and the response is the grant

of two frequencies RXTC2 and TXTC1 for use in further communication by the mobile 21.

The operation is summarised as follows.

When a mobile makes a call request on the control channel requiring use of a traffic (or voice) channel, the control channel signalling will send out both an identification of the traffic channel mobile receive frequency (base station transmit frequency) to be used in the call for use by any or all called mobiles; and an identification of the traffic channel transmit frequency to be used by the transmitting (calling) mobile. Both of these indications of frequencies may be sent in an encrypted manner. During the call, the system may also send out on the traffic channel, by sub-audible data or some other means such as embedded signalling, an identification of the current control channel mobile transmit frequency. this may be encrypted if required. This will permit a mobile station currently receiving to have immediate knowledge of the control channel mobile transmit frequency. Should such a mobile now wish to transmit, it may return to the control channel and transmit at an appropriate time without having to wait for the periodically transmitted control channel transmit frequency identification. During the call, the system may also send out on the traffic channel, by sub-audible data or some other means such as embedded signalling, an identification of the current control channel mobile receive frequency. This may be encrypted if required. This permits the control channel frequency to be dynamically changed at frequent intervals, without loss of service or performance to mobile users currently in calls.

Whenever a change of control channel is required, either periodically or because of jamming; new frequencies may be selected independently for both transmit and receive from the available pool. Transmit and receive frequencies may be separately changed at different times in response to different situations. The pool of frequencies may either be fixed for that site, or allocated for example by a central controller, from a pool available to the system. Prior to the channel changing, the control channel can broadcast the number associated with the channel to which it is changing; in an encrypted manner if required. The control channel may commence transmitting on the mobile receive frequency (base transmit frequency) and will transmit amongst its data an identification of its current receive frequency.

Whenever a traffic channel is allocated for a call, both its transmit and receive frequencies may be selected from the relevant available pool;

and transmit and receive frequency assignments sent independently to mobiles.

Either the transmit or the receive frequency, or both, of a traffic channel could be dynamically changed during a call in progress. The new frequencies could be selected from the available pool, and signalled both on the control and traffic channels.

The arrangement described has the advantage that the system is substantially more immune to jamming. There is no constant duplex spacing, making simple jamming equipment ineffective. Additionally, there is no fixed relationship between transmit and receive frequencies; hence knowledge of the base station transmit frequency does not imply knowledge of the base station receive frequency.

Fault tolerance of the system is increased because loss of one transmitter or receiver on site need not automatically remove both frequencies from the available pool on that site.

Tolerance to interference other than jamming is increased. Receiver frequencies can be allocated to sites or calls independently from transmit frequencies. For example, if co-channel interference from other users of a frequency is detected on a site, that frequency may be held from assignment at that site, and replaced with another from the system's pool.

Independent assignation of receive frequencies can provide freedom from limitations imposed by transmitter combining configurations. With fixed duplex spacing, the ability to change frequencies is often limited by the bandwidth of transmitter combiners. If the receive frequencies are able to change independently, flexibility is obtained in altering base station receive frequencies to avoid interference even if transmitter frequencies remain fixed.

The indication of control channel mobile transmit frequency "over the air" can permit system load management, for example by allocating two possible control channel mobile transmit frequencies at once. This can divide the load of inbound traffic from mobiles, increasing throughput at times of heavy contention. It can also provide faster re-access for mobiles already in calls, by assigning a different frequency (such as by means of sub-audible or other data on a traffic channel) for system re-access to that used for initial access or call request.

Claims

1. A method of operation of a trunking radio system having a base station and at least one remote unit, the method comprising the steps of:

transmitting commands on an outbound control channel frequency and receiving commands on an inbound control channel frequency separated from the outbound control channel frequency by a given duplex separation;

from time to time transmitting commands to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency such that the duplex separation between the inbound control channel frequency and the outbound control channel frequency is varied.

2. A method according to claim 1 wherein the step of transmitting commands to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency comprises transmitting a command to allocate both a new outbound control channel frequency and a new inbound control channel frequency, where the duplex separation between the new outbound control channel frequency and the new inbound control channel frequency is different from the given duplex separation.

3. A method according to claim 1 wherein the step of transmitting commands on the outbound control channel frequency comprises transmitting a command to allocate a pair of an outbound traffic channel frequency and an inbound traffic channel frequency, where the duplex separation between said outbound traffic channel frequency and said inbound traffic channel frequency is not equal to said given duplex separation.

4. A method according to claim 3, comprising further steps of transmitting commands to allocate pairs of outbound and inbound traffic channel frequencies, where the duplex separation between said successive pairs is varied between commands.

5. A method according to claim 3 comprising the steps of setting up a communication link between the base station and the at least one remote unit over the outbound and inbound traffic channel frequencies and

dynamically changing at least one of the outbound and inbound traffic channel frequencies while the communication link is set up.

6. A method according to claim 1, wherein the step of transmitting commands to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency comprises transmitting said commands together with traffic on a traffic channel frequency.

7. A method according to claim 6, wherein the step of transmitting commands comprises transmitting embedded signalling on said traffic channel frequency.

8. A method according to claim 7, wherein the embedded signalling is sub audible signalling.

9. A method according to claim 6 wherein the embedded signalling is by means of a Stealing Channel.

10. A method according to claim 6, wherein the step of transmitting commands to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency comprises transmitting said commands on a control channel frequency as well as transmitting said commands together with traffic on a traffic channel frequency.

11. A method according to claim 1, further comprising the steps of

transmitting traffic on an outbound traffic channel frequency and receiving traffic on an inbound traffic channel frequency separated from the outbound traffic channel frequency; and

from time to time transmitting commands to allocate at least one of a new outbound traffic channel frequency and a new inbound traffic channel frequency such that the duplex separation between the inbound traffic channel frequency and the outbound traffic channel frequency is varied.

12. Trunking radio base station equipment comprising:

a transmitter for transmitting commands on an outbound control channel frequency;

a receiver for receiving commands on an inbound control channel frequency separated from the outbound control channel frequency by a given duplex separation;

a controller having a channel allocation look-up table, the controller being coupled to the transmitter for controlling the transmitter to transmit commands from time to time to allocate at least one of a new outbound control channel frequency and a new inbound control channel frequency selected from the channel allocation look-up table such that the duplex separation between the selected inbound control channel frequency and the selected outbound control channel frequency is varied.

13

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9418960.2

Relevant Technical fields

(i) UK Cl (Edition M) H4L

(ii) Int Cl (Edition 5) H04K & H04Q

Databases (see over)

(i) UK Patent Office

(ii) None

Search Examiner

K LONG

Date of Search

20 DECEMBER 1994

Documents considered relevant following a search in respect of claims 1 to 12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	US 5235598 (MOTOROLA) see particularly column 1 lines 6-10 and column 4 lines 1-7	1

SF2(p)